The relation of the present observations to former ones is shown in the accompanying diagrams (figs. 1 and 2).

[In each observation the six most widened lines in each region are recorded, so that in each 100 observations there are 600 lines in each region. The relative numbers of the lines which are due to iron, nickel, titanium, and unknown substances are graphically represented by the curves. The dotted line refers to the lines of iron, the chain line to those of nickel, the multiple line to those of titanium, and the thick continuous line to those of unknown substances.

The minimum period occurred in 1879, and the maximum at the end of 1883, so that the observations now nearly extend through a Sun-spot cycle.

It will be seen that the conclusion I arrived at in 1886,* namely, that "as we pass from minimum to maximum, the lines of the chemical elements gradually disappear from among those most widened, their places being taken by lines of which we have at present no terrestrial representatives," is supported by the continued observations, especially in the F—*b* region.

The 150 observations now added were made by Messrs. Fowler and Taylor, and reduced and mapped by Messrs. Coppen and Porter.—November 1, 1889.]

II. "On the Cause of Variability in Condensing Swarms of Meteorites." By J. NORMAN LOCKYER, F.R.S. Received June 27th, 1889.

I. THE GENERAL THEORY.

One of the general conclusions I arrived at in my paper on "Researches on the Spectra of Meteorites"† was as follows:—"Most of the variable stars which have been observed belong to those classes of bodies which I now suggest are uncondensed meteor-swarms, or condensed stars in which a central more or less solid condensed mass exists. In some of those having regular periods the variation would seem to be partly due to swarms of meteorites moving round a bright or dark body, the maximum light occurring at periastron."

And again in 1888,‡ referring to the former class, I added, "If the views I have put forward are true, the objects now under consideration are those in the heavens which are least condensed. In this point, then, they differ essentially from all true stars like the Sun. This fundamental difference of structure should be

* 'Roy. Soc. Proc.,' vol. 40, p. 352.
† 'Roy. Soc. Proc.,' vol. 43, p. 154.
‡ 'Roy. Soc. Proc.,' vol. 44, p. 81.

revealed in the phenomena of variability, that is to say, the variability of the bodies we are now considering should be different in kind as well as in degree from that observed in some cases in bodies like the Sun or α Lyræ, taken as representing highly condensed types. There is also little doubt, I think, that future research will show that when we get short period variability in bodies like these, we are here really dealing with the variability of a close companion."

The recent work of Chandler* on the colours of these interesting objects, and the relation of colour to period, furnishes further tests of the theory which I suggested as to their origin.

Variability due to Subsidiary Swarms.

Briefly, this was that in the case of the stars of Group II, which spectroscopic observations show to be composed of uncondensed

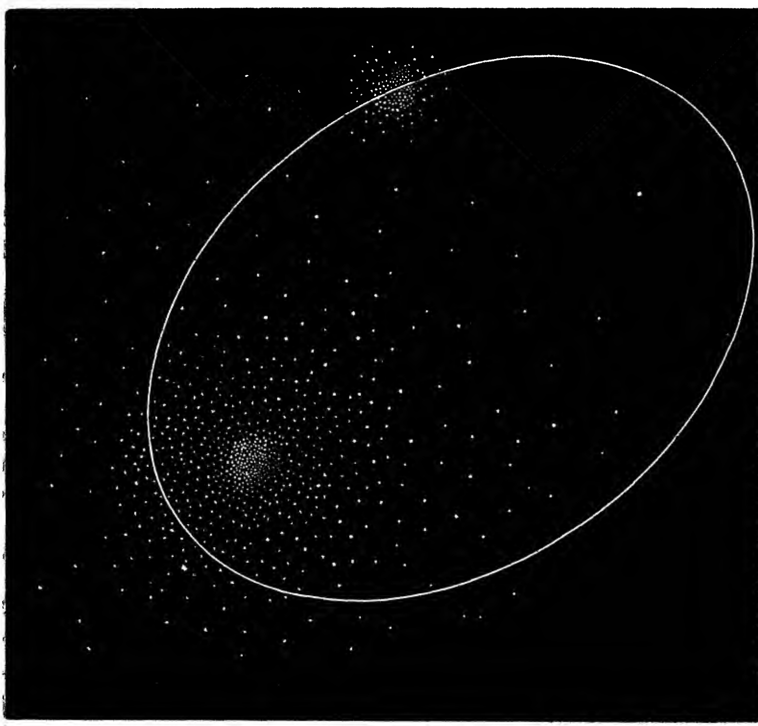

FIG. 1.—Diagram showing the probable origin of variability in condensing swarms.

* 'Astr. Journ.,' No. 179–180.

swarms of meteorites, the variability is produced by the revolution of one or more smaller swarms round the central swarm, the maximum luminosity occurring at periastron passages, when the revolving swarms are most involved in the central one.

Fig. 1 illustrates this suggestion in the simplest case, where there is only one revolving swarm, as in Mira Ceti. The range of variability depends upon the eccentricity of the orbit and the periastron distance of the revolving swarm.

According to this theory, the normal condition is that which exists at minimum, and in this respect it resembles that suggested by Newton, namely, that the increase of luminosity at maximum was caused by the appulse of comets. All other theories take the maximum as the normal condition and the minimum as a reduction of the light by some cause, such as a large proportion of spotted surface or eclipses by dark bodies. In the variables of the Algol type, where the periods are very short, there can be no doubt, after the Henry Draper Memorial photographs, that the eclipse explanation is the true one. But in the variables of Group II, where the period is about a year and the luminosity at maximum in the generality of cases is about 250 times, though in others it runs up to 1600, that at minimum (corresponding to a difference of six magnitudes), it is obvious that the eclipse explanation no longer holds, on account of period, and also that the spotted surface explanation is inadmissable on account of range. If, however, the minimum be taken as the normal condition, and the effects of the revolution of such a swarm as I have assumed be considered, both length of period and range of variability can be explained. In this class of variables the rise to maximum is more rapid than the fall to minimum, and, according to my explanation, the sudden increase is due to the first collision between the two swarms, while the fall to minimum represents the gradual toning down of the disturbance.

Tests of the Theory.

In the Bakerian Lecture (p. 84) I showed how this explanation of variability bore four distinct tests. The first test was that Group II should be more subject to variability than any other group; and I showed that 1 out of every 7 stars of Group II are variable, whilst only 1 in 659 of the stars included in Argelander's catalogue are variable. The other tests were:—(2) when the swarm is least condensed, we shall have the least results from collisions; (3) when it is fairly condensed, the effect at periastron passage (if we take the simplest case, where there is only a single revolving swarm) will be greatest of all; (4) in the most condensed swarms there will be little or no variability, because the outliers of the central swarm may be

drawn entirely within the orbit of the secondary body. I gave tables to show that these tests were satisfied by all the variables included in Dunér's catalogue of red stars.* In the tables which follow, it will be seen that by far the greater number of variables in the group under discussion fall in species 9 and 10, which may fairly be taken to represent the mean condensation, there being in all 15 species. There can, therefore, be no doubt that the three tests just referred to are fully satisfied.

In this paper I propose to further test my theory by the colour observations of Chandler and by the question of irregularity, confining myself to stars known to belong to Group II of which Chandler gives the degree of redness. The stars selected for discussion are the III*a* variables from Gore's revised catalogue.

II. Details of Variables of Group II.

The following tables contain all the particulars of stars with periods varying from 50 to 500 days. Gore's, Chandler's, and Dunér's star numbers are given as well as the star's name. The magnitudes of the variable at maximum and minimum, and also the period, have been taken from Gore.

Colour Notation.

On Chandler's colour scale 0 corresponds to pure white, 1 to white very slightly tinged with yellow, 2 and 3 to deeper yellow tinges, 4 to orange, 5, 6, 7, 8 and 9 to gradually deepening reds, and finally 10 corresponds to the deepest red stars known, such as R Leporis.

The colour notation employed by Dunér is as follows :—

Rrrj	Almost absolute red.
Rrj	Red-yellow foncé.
Rj	Red-yellow.
Jr	Yellow-red.
Jjr..................	Clear yellow-red.

In the Bakerian Lecture for 1888 I gave a series of tables in which the stars of Group II were classed in different species according to their spectra. I have accordingly given with each variable the number expressing the species to which it belongs. In some cases, the details have not been sufficient to assign the star to a definite species, but have been enough to determine whether it was near the first (Species 1) or the last (Species 15). In such cases, the words "early" or "late" are appended. Where the species of a star is doubtful, the word "indeterminate" expresses that fact.

* 'Les Étoiles à Spectres de la troisième Classe.' (Stockholm, 1884.)

Variables with periods of 50 to 100 days.

Gore.	Chandler.	Dunér.	Name.	Max.	Min.	Period.	Colour.		Species.
							Chandler.	Dunér.	
121	5912	184	g(30) Herculis	5	6·2	40—125	3	Jr	8
153	7106	238	S Vulpeculæ	8·85	9·95	67·795	3	Rj	Indeterminate.

Variables with periods of 100 to 200 days.

Gore.	Chandler.	Dunér.	Name.	Max.	Min.	Period.	Colour.		Species.
							Chandler.	Dunér.	
16	845	20	R Ceti	7·9—8·7	< 12·8	167·1	2·4	Jr	9
38	2213	55	η Geminorum	3·2	3·7—4·2	135—151	3	Jr	11
83	4521	127	R Virginis	6·5—7·5	10—10·9	145·7	1·3	Jr	Late.
101	5494	165	S Libræ	8·0	12·5	190	3·0	Rj	Early.
125	5948	—	R Ursæ Min.	8·6	10·5	166	3·2	—	Not in Dunér.
171	7560	261	R Vulpeculæ	7·5—8·5	12·5—13	137·5	2·0	Jr	Indeterminate.
176a	7754	266?	W Cygni	5·8—6·2	6·7—7·3	120—138	5	Rj	9

Variables with periods of 200 to 300 days.

Gore.	Chandler.	Dunér.	Name.	Max.	Min.	Period.	Colour.		Species.
							Chandler.	Dunér.	
60	3170	81	S Hydræ	7·5—8·5	< 12·2	256·4	2·1	Jr	Early.
82	4511	125	T Ursæ Maj.	6·4—8·5	13	255·6	2	Jr	Late.
85	4557	128	S Ursæ Maj.	7·2—8·2	10·2—12·8	224·8	3·2	Rj	Indeterminate.
86	4596	—	U Virginis	7·7—8·1	12·2—12·8	207·4	1·1	—	—
94*a*	5194	158	V Bootis	7·0	9·4	266·5	3·6	Rjj	9
95	5190	157	R Camelopardi	7·8—8·6	12?	258·5	2·1	Rrj	Late.
96	5237	159	R Bootis	5·9—7·8	11·3—12·2	223	2·7	Jr	Early.
124	5950	186	W Herculis	8	11·5	281·2	3·2	Rj	9
125*a*	5955	187	R Draconis	7·0—8·7	< 13	244·5	2·0	Jr	14
135	6512	—	T Herculis	6·9—8·3	11·4—12·7	—	1·4	—	—
148	6905	222	R Sagittarii	7·0—7·2	< 12	270	3·6	Rj	Early.

Variables with periods of 300 to 400 days.

Gore.	Chandler.	Dunér.	Name.	Max.	Min.	Period.	Colour.		Species.
							Chandler.	Dunér.	
11	513	9	R Piscium	7—8·3	< 12·5	345	2	Rj	9
14	806	18	*o* (Mira) Ceti	1·7—5·0	8·7—9·5	331·3	5·9	Rj	10
17	976	23	T Arietis	7·9—8·2	9·4—9·7	324	3·2	Rj	9
23	1577	37	R Tauri	7·4—9·0	< 13	326·6	4·5	Rrj	9
37*a*	2100	—	U (Nova) Orionis	6·1—7·5	< 12	365±	7	—	—
48	2684	68	S Canis Min.	7·2—8·0	< 11	332·2	4·1	Rj	Early.
56	2946	76	R Cancri	6·2—8·3	< 11·7	354·4	5·3	Rj	6
64	3477	91	R Leonis Min.	6·1—7·5	< 11	374·7	6·0	Rrj	10
65	3493	92	R Leonis	5·2—6·7	9·4—10	313	6·9	Rrj	10
71	3825	100	R Ursæ Maj.	6·0—8·1	13·2	302·2	1·6	Jr	Early.
74	3934	106	R Crateris	8	9	395	8·1	Rrj	Early.
80	4407	118	R Corvi	6·8—7·3	11·5	318·6	3·7	Rj	9
103	5504	166	S Coronæ	6·1—7·8	12·5	360·4	4·9	Rj	8
108	5677	170	R Serpentis	5·6—7·6	< 11	357·6	3·7	Rj	Early.
126	6044	192	S Herculis	5·9—7·7	11·5—12·2	303	5·6	Rj	Early.
128	6132	195	R Ophiuchi	7·6—8·1	< 12	302·4	4·5	Rj	7
138*a*	6682	—	— Serpentis	6·8	9	300	5	—	—
146	6849	221	R Aquilæ	6·4—7·4	10·9—11·2	345	5·5	Rrj	9
175	7609	—	T Cephei	6·2—6·7	9·5—9·9	390	6·3	—	—
187	8512	293	R Aquarii	5·8—8·5	11	388	4·3	Jr	9

Variables with periods of 400 to 500 days.

Gore.	Chandler.	Dunér.	Name.	Max.	Min.	Period.	Colour.		Species.
							Dunér.	Chandler.	
1	107	3	T Cassiopeiæ	6·5—7·0	11—11·2	436	Rrj	7·3	Early.
2	112	4	R Andromedæ	5·6—8·6	< 12·8	404·7	Rrj	5·0	10
32	1855	—	R Aurigæ	6·5—7·4	9·2—12·7	465	—	6·5	—
34	1944	—	S Orionis	8·3—9	< 12·3	413	—	6·4	—
89	4826	141	R Hydræ	4—5	10?	434±	Rr	5·9	10
119	5889	181	U Herculis	6·6—7·7	11·4—11·6	408·3	Rrj	6·5	7
151	7045	231	R Cygni	5·9—8	13	425·3	Rrj	6·0	Late.
154	7120	239	χ Cygni	4—6	12·8	406·5	Rrj	6·3	10
189	8600	—	R Cassiopeiæ	4·8—6·8		429±	—	6·5	—

III. The Relation of Colour to Period.

Mr. Chandler's Observations.

In the tables given the particulars relating to period and range of variability are taken from Gore, and Chandler's colour-numbers are placed in a separate column.

Mr. Chandler has shown* that there is an intimate connexion between the length of period of a variable star and its colour. In general, the longer the period the redder the tint. If the period is between 500 and 600 days, the mean redness on his scale is about 7·5; for periods of about 300 days, it is about 3; and for shorter periods it is 1 or 2. This is exactly what would happen if my theory were true.

In order to investigate the cause of this relation it is necessary that I should refer to Chandler's work in connexion with my previous classification of the 297 bodies of Group II spectroscopically observed by Dunér.

The Relation of Colour to the Degree of Condensation in Swarms of Group II.

In the Bakerian Lecture I provisionally divided the bodies of Group II into fifteen species, the first being the least and the last the most condensed swarms. If then the degree of condensation of a swarm has any relation to colour, the work of Chandler on the colours of variable stars, taken in conjunction with this classification, ought to enable us to determine the nature of such relation.

In order to determine Chandler's colour-numbers corresponding to these, tables were prepared comparing Dunér's colours of the variable stars of the group with the colours assigned by Chandler to the same stars. Two stars which Dunér gives as Rrrj occur in Chandler's list, the colours being 6·9 and 8·1 respectively, or a mean of 7·5.

The colour-number corresponding to Rrrj has therefore been taken as 7·5. Similarly, there are ten Rrj stars in Dunér's list for which the mean colour-number assigned by Chandler is 5·9, and so on.

Dunér's Colour = Rrrj.

No. (Dunér).	Colour (Chandler).
92	6·9
106	8·1
	Mean 7·5.

* 'Astr. Journ.,' No. 179—180.

Dunér's Colour = Rrj.

No. (Dunér).	Colour (Chandler).
37	4·5
91	6·0
221	5·5
3	7·3
4	5·0
141	5·9
181	6·5
231	6·0
239	6·3
269	6·2
	Mean 5·9.

Dunér's Colour = Rj.

196	5·0
238	3·0
165	3·0
266	5·0
128	3·2
158	3·6
186	3·2
9	2·0
18	5·9
23	3·2
68	4·1
76	5·3
118	3·7
166	4·9
170	3·7
192	5·6
195	4·5
50	6·0
	Mean 4·2.

Dunér's Colour = Jr.

281	2·0
184	3·0
20	2·4
55	3·0
127	1·3
261	2·0
81	2·1

No. (Dunér).	Colour (Chandler).
125	2·0
159	2·7
187	2·0
222	3·6
100	1·6
293	4·3
29	2·0
	Mean 2·4.

Dunér's colour = Jjr.

None common to Dunér and Chandler.

Mean colour, say, 0·7.

It will be seen that the increments for one colour stage of Dunér are 1·6, 1·7, and 1·8 respectively, or a mean of 1·7. Since there are none of Dunér's Jjr stars in Chandler's list, we may use this increment to approximate to the colour; this gives us the number 0·7. We thus get:—

Dunér's colour.	Chandler's number.
Rrrj	7·5
Rrj	5·9
Rj	4·2
Jr	2·4
Jjr	0·7

Using these mean numbers, we may determine the mean colour-number associated with each of the fifteen species into which Group II has been divided. The following tables show the results obtained.

	Dunér's No.	Colour.
Species 2.	56	4·2
	93	4·2
	220	2·4
	223	2·4
	246	2·4
		Mean 3·1.
Species 3.	42	2·4
	53	2·4
	70	2·4
	185	2·4
	198	2·4
	228	4·2
	276	0·6
	290	2·4
		Mean 2·4.

	Dunér's No.	Colour.
Species 4.	7	0·6
	95	2·4
	110	2·4
		Mean 1·8.
Species 5.	89	4·2
	153	2·4
	154	2·4
	173	2·4
	253	4·2
	258	2·4
	267	2·4
	271	2·4
		Mean 2·85.
Species 6.	6	2·4
	19	2·4
	39	2·4
	48	4·2
	67	2·4
	74	2·4
	76	4·2
	83	2·4
	99	2·4
	188	4·2
	189	4·2
	194	2·4
	202	2·4
	208	4·2
	214	4·2
	227	2·4
	247	2·4
	254	4·2
	259	2·4
	260	2·4
	273	4·2
	274	2·4
	285	2·4
	289	0·6
		Mean 2·9.
Species 7.	24	0·6
	97	2·4
	115	2·4
	143	2·4

	Duner's No.	Colour.
	181	5·9
	195	4·2
	229	2·4
	241	4·2
	249	4·2
	252	4·2
	256	4·2
	269	5·9
	270	4·2
	275	4·2
	284	2·4
		Mean 3·6.
Species 8.	15	2·4
	29	2·4
	57	4·2
	88	2·4
	103	2·4
	108	2·4
	112	0·6
	137	4·2
	161	4·2
	166	4·2
	184	2·4
	216	4·2
	225	4·2
	230	2·4
	242	2·4
	251	4·2
	263	2·4
	278	2·4
	283	2·4
	286	2·4
	291	2·4
	295	2·4
	297	2·4
		Mean 2·9.
Species 9.	9	4·2
	12	5·9
	20	2·4
	23	4·2
	25	2·4
	37	5·9
	44	4·2

	Dunér's No.	Colour.
	65	2·4
	66	2·4
	118	4·2
	123	5·9
	148	2·4
	156	5·9
	158	4·2
	162	4·2
	165	4·2
	174	4·2
	175	4·2
	176	4·2
	183	4·2
	186	4·2
	204	4·2
	217	4·2
	221	5·9
	237	2·4
	255	2·4
	266	4·2
	277	2·4
	281	2·4
	293	2·4
		Mean 3·9.
Species 10.	4	5·9
	18	4·2
	28	4·2
	30	4·2
	86	4·2
	91	5·9
	92	7·5
	131	2·4
	141	5·9
	172	5·9
	196	4·2
	232	4·2
	239	5·9
		Mean 5.
Species 11.	5	2·4
	55	2·4
	87	4·2
	98	2·4
	135	2·4

	Dunér's No.	Colour.
	149	4·2
	152	2·4
	171	2·4
	177	2·4
	191	2·4
	193	2·4
	197	2·4
	199	2·4
	212	2·4
	218	4·2
	234	2·4
	245	2·4
	288	2·4
		Mean 2·7.
Species 12.	27	2·4
	46	2·4
	51	2·4
	52	2·4
	60	2·4
	78	4·2
	117	2·4
	122	0·6
	126	2·4
	129	2·4
	133	2·4
	164	4·2
	215	2·4
	264	2·4
		Mean 2·5.
Species 13.	1	2·4
	2	4·2
	16	0·6
	17	2·4
	26	0·6
	32	2·4
	33	2·4
	36	2·4
	38	4·2
	40	2·4
	54	4·2
	61	2·4
	62	2·4

	Dunér's No.	Colour.
	64	2·4
	69	2·4
	71	2·4
	75	2·4
	82	0·6
	104	2·4
	109	2·4
	116	2·4
	120	2·4
	121	2·4
	124	2·4
	130	2·4
	132	2·4
	144	2·4
	145	2·4
	146	2·4
	155	2·4
	160	2·4
	182	4·2
	200	0·6
	203	2·4
	205	2·4
	207	2·4
	211	2·4
	240	2·4
	243	2·4
	244	2·4
	268	2·4
	280	2·4
	287	2·4
	292	2·4
	294	2·4
		Mean 2·4.
Species 14.	22	2·4
	49	2·4
	90	2·4
	94	2·4
	107	2·4
	111	4·2
	113	2·4
	140	2·4
	142	2·4
	167	2·4

	Dunér's No.	Colour.
	169	2·4
	179	2·4
	180	2·4
	187	2·4
	250	4·2
	282	0·6
	138	2·4
		Mean 2·5.
Species 15.	41	2·4
	50	4·2
	96	2·4
	101	2·4
	136	4·2
	139	2·4
	147	0·6
Species 15.	190	4·2
	226	2·4
	235	2·4
	265	2·4
	279	2·4
		Mean 2·7.

We thus get the following colour-numbers corresponding to the fifteen species :—

Species.	Mean colour-number.
1 (1 star) (?)	4·2
2 (5 stars)	3·1
3 (8 ,,)	2·4
4 (3 ,,)	1·8
5 (8 ,,)	2·85
6 (24 ,,)	2·9
7 (15 ,,)	3·6
8 (23 ,,)	2·9
9 (30 ,,)	3·9
10 (13 ,,)	5·0
11 (18 ,,)	2·7
12 (14 ,,)	2·5
13 (45 ,,)	2·4
14 (17 ,,)	2·5
15 (12 ,,)	2·7

The remaining stars observed by Dunér are not included in the classification at present, owing to insufficient details.

The result of this comparison of Dunér's and Chandler's observations, taken in conjunction with my classification in species of the bodies of Group II, goes to show that the swarms with a mean condensation are the reddest. For, although the results are not quite so uniform as might be desired, there is a decided maximum of redness in species 9 and 10, which may fairly be taken as the swarms with mean spacing. The greatest discrepancy is in Species 1, but here the result depends upon the observations of one star, and even that is not definitely known to belong to Species 1. (See "Bakerian Lecture," p. 65.)

It may be objected that the foregoing series of numbers is not sufficiently regular for any trustworthy conclusions to be arrived at. But the very decided maximum in Species 10 is of itself sufficient evidence that the irregularities on both sides of it are due to the difficulties of observation. I have gone over Dunér's observations of the spectra and colours of the bodies of Group II without reference to my temperature classification, and the result shows that where the spectra are described as identical, the colours sometimes differ considerably. The table on page 419 shows that this is the case. The numbers in the vertical columns indicate the numbers of stars of any particular colour associated with a particular spectrum. Thus, amongst the stars with a spectrum containing the band 1—10 uniformly developed, 3 have the colour Rrj, and 5 are Rj.

It will be seen, therefore, that, even if my classification into species be not accepted, the relation between colour and spectrum in the present state of our knowledge is not absolutely definite.

[This is probably to a great extent due to the variability of the stars of the group. All of them may be more or less variable, and it may often have happened that the colour of a star has been recorded at one time and its spectrum at another, when the colour was slightly different. Some of the slight variations observed may also be due to variation in the atmospheric absorption.—November 1, 1889.]

On reference to the tables of variables which I give in this paper it will be seen also that the relation between colour and period observed by Chandler is only a general one.

We may, therefore, for the present regard the swarms with mean spacing as the reddest. The sparsest swarms vary from blue to greenish-white, so that the redness will gradually deepen in passing from these to the mean swarms. Again, in passing from the mean swarms to the most condensed ones, the redness must gradually disappear, for we know that the stars of Group III are yellow or white.

The following represents the colour-condition of stars of Group II both more and less condensed than the mean swarms.

Spectra.	Rrj.	Rj.	Jr.	Jjr.
Bands narrow and pale, red stronger.............	—	2	10	—
2—8 bands narrow and pale....................	—	—	15	—
Bands wide and pale..........................	3	5	9	—
2—8 bands moderately wide and dark, 2 and 3 strong	—	5	36	4
Bands wide and dark, red strongest.............	—	—	3	2
2—9 bands moderately wide and dark, 2 and 3 strongest	—	4	6	—
1—9 bands moderately wide and dark, 2 and 3 strongest	—	1	2	—
1—10 bands wide and moderately dark, red strongest	—	—	1	—
1—10 bands well developed and equal	3	5	—	—
1—9 blue bands most strongly developed.........	—	1	1	—
1—9 wide and dark	—	5	4	—
2—9 wide and dark, blue strongest	1	5	4	1
2—9 wide and dark	1	5	21	—
2—10 wide and dark	—	3	—	—
Bands wide and dark, blue strongest.............	4	13	5	—
2—8 wide and dark, blue strongest	—	1	—	1
Bands wide and dark.............................	5	10	6	1
2—8 wide and dark...............................	—	6	20	1
2—8 narrow and dark	—	1	1	—
Bands narrow and pale, blue strongest	—	—	5	—
2, 3, 4, 5, 7 and 8, 7 and 8 strongest..........	—	2	6	—
2, 3, 5, 7, 8...................................	—	—	2	1
2, 3, 7, and 8	—	1	6	1
2, 3, 7	—	3	3	—
Indeterminate...................................	3	8	10	—
	20	86	176	12

Group II.... { reddish-yellow,
yellowish-red,
red,
yellowish-red,
reddish-yellow.

Hence no definite conclusion as to temperature of Group II stars can be arrived at by colour observations alone, since stars cooler than the mean, as well as hotter, give the same colour.

The Cause of the Relation between Colour and Period.

On reference to the tables of variables, it will be seen that there are none less condensed than Species 7. This means that the sparsest swarms either exhibit no variability at all, or their variability is of such a character as to escape notice. The reason for this is not far to seek. Firstly, if there be any revolving swarms with small orbits, they will never be entirely out of the central swarm, and their effect will simply be to produce a general increase of brightness of the swarm.

Only revolving swarms with large orbits will therefore be effective in producing variability, but even these will only cause variability of short range, since the number of collisions at periastron passage will be small, the swarm being sparse. In the sparsest swarms, therefore, the variability will be of a long period and the range will be small. These are no doubt the causes of the variability having been overlooked.

When we pass to the mean swarms, however, the variability becomes more strongly marked. Cometic swarms of short period, if they exist at all, will still only produce a general brightening of the central swarm, and the swarms most effective in producing variability will therefore be those with moderately long periods. The range of variability will depend upon the eccentricity of orbit and the periastron distance of the revolving swarm, as in the general case.

As the central swarm becomes more and more condensed, and therefore gradually loses its redness, only shorter period swarms will be effective in producing variability, as the outliers will have been drawn entirely within the orbits of longer period swarms, if they exist at all.

Still further condensation of the central swarm will draw the outliers within the orbits of the revolving swarms, which would produce variability in the swarms last considered, and now only very short period swarms are concerned. At the same time the colour will have become yellow or yellowish-white, the swarm having passed from Group II to Group III.

It will be seen that my theory perfectly explains the general relation of period to colour which has been observed by Chandler and previously by Schmidt,* and in fact demands it.

The range of variability does not appear to bear any relation to the periodicity (except perhaps in the sparsest swarms), and this is only what we should expect, as the conditions on which the range depends (periastron distance, and eccentricity of orbit of revolving swarm) are special to each star. Cometic swarms in our own system follow no general rule as regards the eccentricities of their orbits, or their perihelion distances.

IV. The Irregular Variables of Group II.

The next test is that of irregularity. The apparent irregularities in the variability of stars in the group under discussion are, on my theory, produced by the revolution of several swarms of meteorites at different rates and different distances round the central one. The swarms most subject to irregularity should, therefore, on this view, be those which are most likely to suffer from the effects of the

* Quoted in 'Observatory,' Feb., 1889.

greatest number of revolving swarms. These will not be the sparsest swarms, for the reason that the short period swarms will only produce a general brightening, as already pointed out, leaving the long period swarms predominant. Neither will they be the most condensed, because most of the cometic swarms will sweep clear of the central swarm at periastron passage. They must, therefore, occur in the swarms of mean condensation, if anywhere at all, though mean swarms need not necessarily exhibit irregular variability. The facts observed show that out of the five irregular variables of Group II, three have colours indicating a mean condensation, while two appear to be a little further condensed.

Irregular Variables.

Gore	Chandler.	Dunér.	Name.	Maximum.	Minimum.	Period.	Colour.		Species.
							Chandler.	Dunér.	
18	1072	29	ρ-Persei	3·4–	4·2	—	2	Jr	8
37	2098	50	α-Orionis	1	1·4	—	6	Rj	15
129	6181	196	α-Herculis	3·1	3·9	—	5	Rj	10
179	7803	269	μ-Cephei	2·7	4·8	—	6·2	Rrj	7
184	8273	281	β-Pegasi	2 2	2·7	—	2	Jr	9

The spectroscopic observations confirm the conclusion that irregularity mostly occurs in mean swarms; it will be seen that with the exception of α Orionis, which is only very slightly variable, the species to which the irregular variables belong are 7—10, indicating mean condensation.

V. Bright Hydrogen in Variable Stars of Group II.

I have already pointed out* that in the class of variable stars under consideration the bright lines of hydrogen might be expected to make their appearance at maximum. For since the bodies of Group II are very much akin to nebulæ, an increase of temperature such as occurs at maximum should be accompanied by the appearance of bright hydrogen, because a greater quantity of incandescent gas would then occupy the interspaces.

Under normal conditions there are neither bright nor dark hydrogen lines in the spectra of bodies of Group II, the simple and sufficient explanation being that the bright lines from the interspaces balance the dark lines from the meteoritic nuclei. "Anything which in this condition of light-equilibrium will increase the amount of incan-

* Bakerian Lecture, 1888, p. 83.

descent gas and vapour in the interspaces will bring about the appearance of the hydrogen lines as bright ones. The thing above all things most capable of doing this in a most transcendental fashion is the invasion of one part of the swarm by another moving with a high velocity. This is exactly what I postulate. The wonderful thing under these circumstances then would be that bright hydrogen should *not* add itself to the bright carbon, not only in bright line stars, but in those the spectra of which consist of mixed flutings, bright carbon representing the radiation."*

That the bright lines of hydrogen do make their appearance at maximum, in some of the stars at all events, is placed beyond doubt by the recent observations of Mr. Espin at Wolsingham.

On August 13, 1888, Mr. Espin† noted "a very bright line, apparently F," in the spectrum of R Cygni, the maximum of the star occurring on July 19th.

The spectrum of *o* Ceti was also observed by Mr. Espin† on October 23rd and 30th, 1888, the maximum of the star occurring on September 28th. Dunér's bands from 1 to 10 were seen, and the observer noted that on October 30th, when the star had faded considerably, bands 8, 9, and 10 seemed to be broken into two, but he was doubtful whether these interferences were due to bright lines or not. A brilliant line was observed in the violet, which was thought to be *h* (hydrogen). It is very probable also that bright F was present on this date and caused the second maximum in band No. 9.

Bright lines of hydrogen and other substances were photographed in the spectrum of Mira by Professor Pickering in November, 1886, the maximum occurring on November 14th.

Mr. Maunder‡ observed bright hydrogen (G) in the spectrum of Mira on October 5th, 1888, but on December 1st it was not recorded.

Mr. Espin has also announced in a recent circular (April 2nd, 1889) that there are bright lines in the spectra of R Leonis and R Hydræ. He states that "the spectra of R Leonis and R Hydræ contain bright (hydrogen?) lines, first seen on February 25th. Observations confirmed, through the kindness of Mr. Common, by Mr. Taylor, at Ealing, who sees two in R Leonis and one in R Hydræ." Both these stars were near their maxima at the time of observation, that of R Leonis occurring on March 23rd, and that of R Hydræ on February 17th.

[Another circular (October 3, 1889) states that "Bright lines were seen in the spectrum of R Andromedæ on September 25th, the F line being very bright." The maximum occurred on July 25th.—November 1, 1889.]

* Bakerian Lecture, p. 83.

† 'Ast. Soc. Monthly Notices,' vol. 49, p. 18.

‡ 'Ast. Soc. Monthly Notices,' vol. 49, p. 304.

The appearance of the hydrogen lines at the maximum and their disappearance as the stars fade will no doubt eventually be found to be among the characteristic variations of the spectrum which accompanies the variation of light in stars of this class.

VI. Conclusion.

As far as Group II is concerned, I think it will be granted that the meteoritic theory of variability is quite in harmony with the facts observed, considering that the observations are still incomplete. The theory does not require that all the swarms of the group should be variable, but only those which are condensing double or multiple nebulæ. At the same time it requires that this group should be more subject to variability than any of the others, and this is one of the best established facts of modern astronomy. Not only are these general demands satisfied, but the theory bears the strain put upon it when it is used to explain the finer details, as I have shown in this paper.

III. "On the Local Paralysis of Peripheral Ganglia, and on the Connexion of different Classes of Nerve Fibres with them." By J. N. Langley, F.R.S., Fellow of Trinity College, and W. Lee Dickinson, M.R.C.P., Caius College, Cambridge. Received September 7, 1889.

Hirschmann* has shown that after a moderate dose of nicotin stimulation of the sympathetic nerve in the neck causes no dilation of the pupil. He concludes that nicotin paralyses the endings of the dilator fibres in the pupil.

In the course of some observations on the physiological action of nicotin, we had occasion to repeat Hirschmann's experiment; we found in the rabbit that 30 to 40 mgrms. of nicotin injected into a vein stopped the effect of stimulating the sympathetic in the neck, not only on the pupil, but also on the vessels of the ear. A paralysis of the vasomotor fibres of the sympathetic had been suggested by Rosenthal,† on the ground that nicotin causes a state of congestion in the vessels of the ear of the rabbit.

Since we had been much struck with the profound action of nicotin upon the central nervous system, and since it had seemed to one‡ of us in some previous experiments with atropin that the secretion of saliva from the sub-maxillary gland of the cat failed earlier on stimu-

* Hirschmann, 'Arch. f. Anat. u. Physiol.,' 1863, p. 309.

† Rosenthal, 'Centralb. f. d. Med. Wissenschaften,' 1863, p. 737.

‡ Langley, 'Journal of Physiology,' vol. 1, 1878, p. 89.

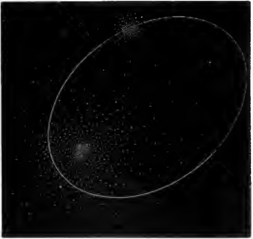

FIG. 1.—Diagram showing the probable origin of variability in condensing swarms.